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Wheel Diameter and Width Influence in Variability of Brake Data Measurement at Ministry of Transport Facilities

Carolina Senabre, Sergio Valero, Emilio Velasco

***Abstract*—**The brake systems of vehicles are tested periodically by a “brake tester” at Ministry of Transport (MOT) stations. This tester measures the effectiveness of vehicle. This parameter is established by the International Committee of Vehicle Inspection (CITA). In this paper, we present an investigation of the influence of the tire size on the measurements of brake force on three MOT brake testers. We performed an analysis of the vehicle braking capacity test at MOT stations. The influence of varying wheel diameter and width on the measurement of braking at MOT stations has been analyzed. Thereby, the MOT brake tester as a verification system for a vehicle has been evaluated.

***Keywords*—**Brake tester, wheel diameter, Ministry of transport facilities.

I. Introduction

THE objective of this research is to compare the differences of brake measurements obtained with the same vehicle, with two different wheels, with different diameter and width, when braking on three Maha MOT brake testers. All parameters of the vehicle have been controlled to be the same at all tests. Therefore, brake measurements variability will be due different diameter and width of wheel used and to the Maha tester used.

II. Procedure

A. Review

Periodically, the brake circuit of your vehicle has to be checked by the Ministry of Transport Facilities. This inspection includes a brake test made on a roller bed. This research analyses how far the tire diameter affect the measurements taken on three Maha testers. The question to be answered is: When a vehicle uses a higher wheel diameter, will this increase the probability to pass the test? To sum up, we study if the MOT brake tester correctly assesses the condition of brakes 100% efficiently.

III. Mathematical Demonstration

To know which parameters influence on the brake measurement on any brake tester, we have to analyze mathematically the brake equations. Considering:

- r_e= Effective radius of the wheel on rollers.
- r_2=r_3 radius of rollers,
- M = Sum of moments,
- Mf = Braking torque applied to the vehicle wheel
- Mt = Roller tractor torque
- Mt_2 = Mt_3,
- F2 = F3 = Roller tractor force
- Fr = Frictional force, Fr_2=Fr_3
- M_{fr}= Frictional torque
- μ = Rollers roughness
- P = Weight on the wheel
- Re = Effective radius of the wheel
- Cos θ = Angle between the symmetry axis and the line between wheel-roller centers.

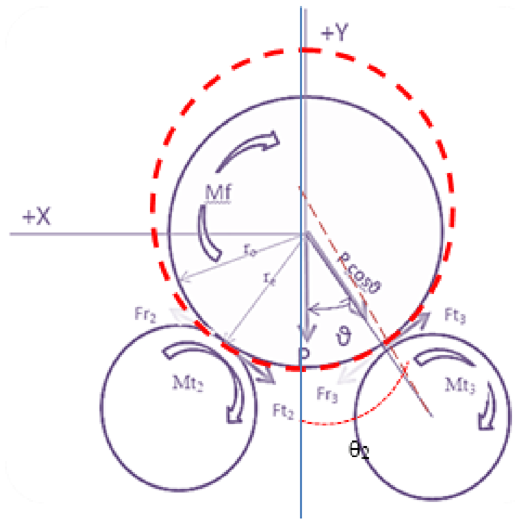

Fig. 1 Parameters in the brake test on rollers

On roller bank, there is not acceleration. Considering, I= Inertia, and α= acceleration, then:

$$I.\alpha=0 \quad (1)$$

Equations of the braking torque on roller bed are provided:

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$$\Sigma M = Mt - Mf - Mr = I * \alpha \quad (2)$$

$$Mf = 2r_e F_3 - I.\alpha - 2Fr_3.r_e \quad (3)$$

$$Mf = 2r_e F_3 - I.\alpha - 2r_e.\mu.P \cos\vartheta \quad (4)$$

If I.α=0

$$\mathbf{Mf = 2Mt - 2\ \mu.P \cos\vartheta\ {*}r_e} \quad (5)$$

Braking torque will depend primarily on factors such as [5]-[8]:

- The effective radius of wheel on rollers.
- Tire pressure
- Acceleration during the test
- The separation of the rollers and the cos ϑ
- The weight on wheel
- The adhesion of the wheels on the ground or rollers and the rolling resistance.
- The adhesion will depend on tire tread on the roller.

IV. Experimentation

The vehicle used in the research was a Volkswagen Passat, diesel. It is equipped with advanced Electronic Stabilisation Programme (ESP) and the anti-lock braking system (ABS). ESP detects critical situations and acts fast to stop skidding before it begins. ABS stops wheels locking.

The test on the brake roller tester at the MOT centre is carried out by placing the vehicle on rollers. The emergency brake should not be actuated. The car stops on the roller bed [1]. Then the rollers rotate at 3-5 km/h of speed. This velocity is indicated in the "MOT procedure manual" [2] from Ministry of Industry, Tourism and trade of Spain (2006) [3]. Brake pedal will be pressed until 100% of slippage is obtained. Each of these measurements was obtained by taking the average of ten braking data sets with the same conditions; dispersion of each group of brake measurements was less than 3%.

Fig. 2 Vehicle on the brake roller tester at the MOT centre of Elche

The braking state is checked by measuring brake effectiveness. Efficacy must overcome a rejection threshold of 50% [1]-[4], which is the same for all Spanish MOT brake testers independent of the characteristics of the individual MOT brake test used.

The efficiency is [2]-[4]:

$$E = \frac{F_{total}}{m * g} 100 \quad (6)$$

where, E= % of efficiency, minimum 50%, F= Sum of braking forces of all wheels. Braking forces on Front wheels (Ffw) + Braking forces on Rear wheels (Frw), m= Maximum permissible vehicle mass in kg=1550 kg/vehicle+ 70 kg/driver=1620 kg, g = acceleration of gravity, 9.8 m/s^2.

The vehicle breaks 60% with front wheels and 40% with rear wheels. Then, the minimum force applied on front wheel to pass the MOT test is:

$$\text{Ffw} = \frac{E*m*g}{100}\frac{60\%}{2} = 50\%/100 * 1620\ \text{kg} * 9.8\ \text{m/s}^2 * 0.3 = 2234.4\ \text{N} = 238{,}14\ \text{DaN} \quad (7)$$

$$\text{Frw} = \frac{E*m*g}{100}\frac{40\%}{2} = 50/100 * 1620\ \text{kg} * 9.8\ \text{m/s}^2 * 0.2 = 1587.6\ \text{N} = 158.7\ \text{DaN} \quad (8)$$

It has been demonstrated in previous investigations that the roller base can vary the brake force needed to stop the wheel. Therefore, three MOT brake testers have been used to analyze the influence of the variation of the wheel radius vs the roller base [8], [9].

As can be seen in Table I and Figs. 3-5, the brake testers used have different characteristics.

TABLE I
3 MOT Brake Testers from Elche City MOT Station

MAHA IW2 RS2 MBT 4000		
Roller diameter (mm)	Distance between rollers (mm)	Velocity of the test (km/h)
202	430	2,3 - 4,6 km/h
MAHA IW7	Serie MBT 7000	
Roller diameter (mm)	Distance between rollers (mm)	Velocity of the test (km/h)
265	475	3 - 6 km/h
MAHA IW2 RS5		
Roller diameter (mm)	Distance between rollers (mm)	Velocity of the test (km/h)
202	400	5 km/h

MOT brake tests from Elche city MOT station can be seen in Figs. 3-5:

- MOT Brake tester MAHA IW2 RS2 MBT 5000,
- MOT Brake tester MAHA IW7 Serie MBT 7000,
- MOT Brake tester MAHA IW2 RS Eurosystem,

The MOT Procedure Manual establishes a procedure for checking the equivalence of tire size in brake tests at MOT stations [1]. Any driver can check on the internet which tire size is allowed for his/her vehicle.

The two tire types used during the measurements were: Dunlop 215/55R16 and Hankook Ventus V12 evo2, 235/45ZR17 97Y.

According to previous researches [8]-[11], the braking required to stop the wheel vary as tire pressure increases at

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whichever MOT brake tester is used. Therefore, tires pressure was checked to be the same in all measurements, 1.7 bar.

Fig. 3 MOT Brake tester MAHA IW2 Profi. RS2 MBT 5000

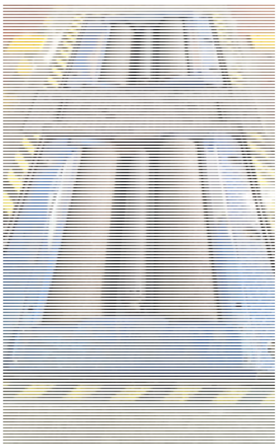

Fig. 4 MOT Brake tester MAHA IW7 Serie MBT 7000

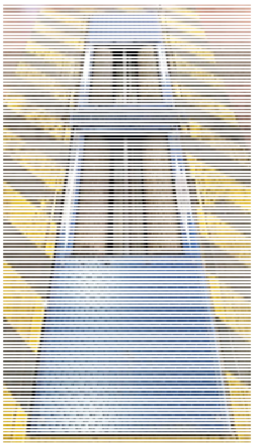

Fig. 5 MOT Brake tester MAHA IW2 Eurosystem

Firstly, tests on MOT brake testers were performed with the same tire: Dunlop 215/55R16 tire, with the same tire pressure, 1,7 bar, to know that the differences obtained in the measures were not due to these parameters. Secondly, the tire used was Hankook Ventus V12 evo2, 235/45ZR17 97Y on the same three MOT brake testers.

Fig. 6 Dunlop 215/55R16

Fig. 7 Hankook ventus V12 evo2, 235/45ZR17 97Y

Brake data results obtained on the three MOT brake testers are shown on Fig. 8.

V. Discussion

When roller base, the roller surface and the tire pressure is constant, if θ2 is lower than θ because the wheel radius is bigger. Then, the brake torque needed to stop the wheel will be lower, as it can be seen in:

$$Mf = 2Mt - 2\ \mu.P\ \cos\vartheta * r_e \qquad (9)$$

When de diameter of the wheel increases:

$$\text{Cos}\ \vartheta_2 > \cos\vartheta \text{ and } r2 > r1 \qquad (10)$$

Therefore,

$$Mf_2 < Mf_1 \qquad (11)$$

Furthermore, when it is used a bigger wheel, the effective radius is longer, so this part of the equation ($-2\ \mu.P\ \cos\vartheta * r_e$) has a higher negative proportion and the resultant brake torque will be lower. Then, the brake torque needed to stop the wheel is lower (when the diameter of the wheel increases), for the same tire pressure and the same tractor torque (Mt).

$$Mf = 2Mt - 2\ \mu.P\ \cos\vartheta * r_e \qquad (12)$$

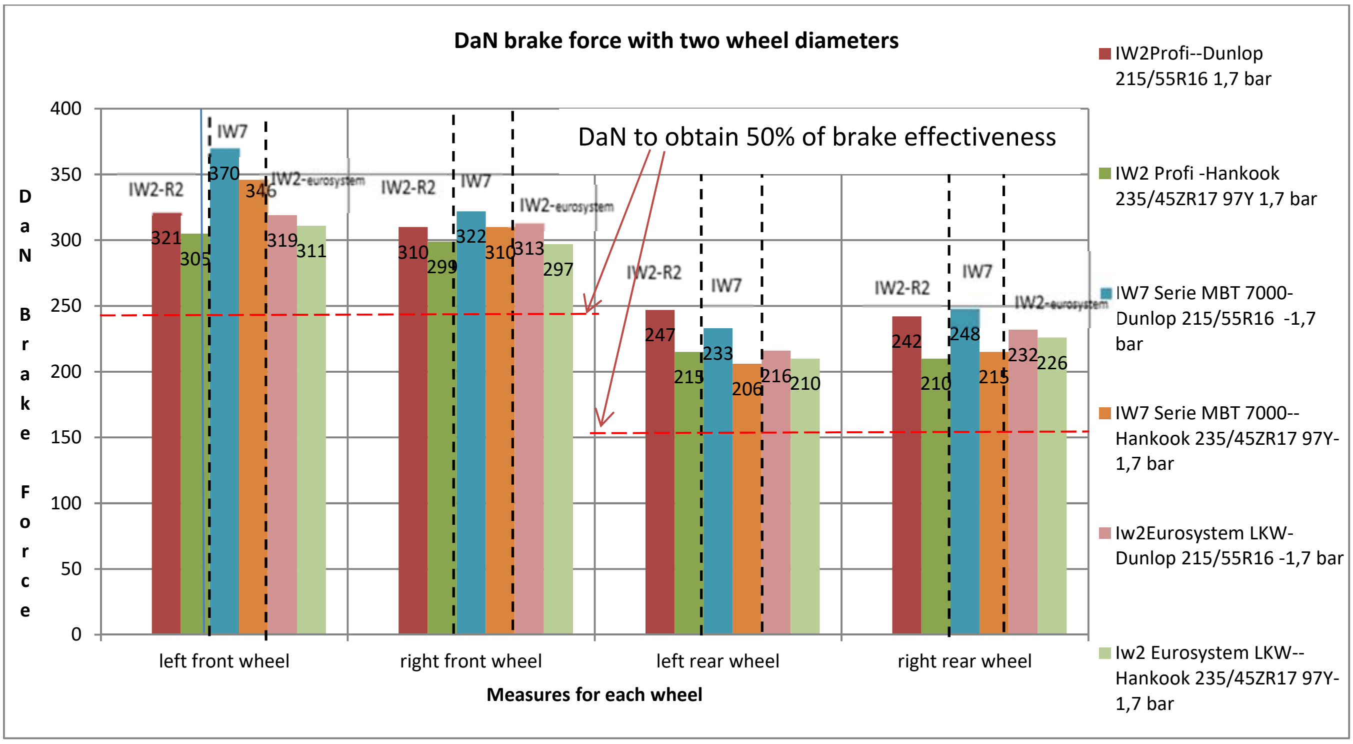

Fig. 8 DaN brake force comparison with two different wheel diameters

On the other hand, a larger width of the wheel increases the value of the Frictional Torque, therefore, it is needed a lower brake value to stop the wheel. In other words, if there is a bigger surface of contact between the wheel and the roller, and the adherence is higher, it will be needed a lower brake torque to stop the wheel. Thus, it has been demonstrated that the measure of brake obtained at MOT testers depends on the condition of the brakes, but also the tire radius, width and the distance between rollers. The tire pressure, roughness of rollers and the weight on the wheel were controlled to be constant during all the experiments. The influences of these parameters have been demonstrated in previous researches [8]-[11].

VI. Conclusion

An objective brake test would be expected when the vehicle is tested at any MOT station. Therefore, it is not expected that brake measurement is influenced by any other parameter. It is only need to know if the brakes are in good condition or not.

Experimental data and mathematical equations demonstrate that brake measurements vary when a bigger wheel is used. Then, it has been demonstrated that brake measurements depend on other factors, extrinsic to the brake system. Although in this case the vehicle passes the exam on the three MOT brake testers used, in other cases, where brake data measured are around the rejection threshold, the vehicle could pass or not the exam depending on the variation due to the tire diameter. It can be concluded that the same vehicle without any problem in the brake system can pass or fail the brake test, depending on the wheel radius and the width of the wheel. Moreover, brake measurements vary depending on which MOT tester is used, due to the variation of parameters such as: The distance between rollers, the roughness of the rollers and the rollers diameter. In addition, the influence of parameters such as tire pressure and the weigh on the wheel have also been demonstrated in previous therefore they were controlled to be the same during al experiments [8]-[11]. So, it can be concluded that these parameters affect the brake measurements at MOT test centers and distort the results of the brake test. Thereby, we can cast doubt on the suitability of a brake roller tester to determine whether the brake system is in good condition.

In order to obtain better results from MOT brake testers we recommend that all Spanish MOT stations should have the same characteristics, such as: Distance between the rollers, the same roller surface, and the same roller diameter. At least, the tire pressure and the weight on the wheel should be controlled, but it is impossible that all vehicles performed the test with the same tires, therefore, the variation due to the tire diameter will never be controlled.

The best solution would be to use a MOT brake tester without drag of the vehicle wheels**.**

Acknowledgment

The author would like to thank for the grant: “Ayudas para la realización de Proyectos I+D para grupos de investigación emergentes” GV/2015/034.

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